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Silviculturist's Point of View on Use of Nonlocal Trees

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Abstract

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Describes important factors that affect the health and vigor of forest trees introduced into communities and high density recreation areas. Seed origin, climatic and edaphic factors, and mycorrhizae are discussed first followed by insects, diseases, animal damage, and species selection. Relevant literature is covered along with observations and experience. Treatise is intended to point out the critical considerations in use of nonlocal trees and to serve as a reference guide in making wise species selection.

Keywords: Recreation area planting, seed origin, urban trees.

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Silviculturist's Point of View On Use of Nonlocal Trees[1]

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Introduced trees have enriched the environmental quality of communities, recreation areas, and road right-of-ways throughout the world. On wooded areas, man had to cut down trees that occupied the space he needed to build his home, campsite, or road. On barren areas, man went out to find a tree to provide shade and beauty.

Man has not always been fully satisfied with the native trees surrounding his urban house, if indeed there were any. His favorite tree from "back home" was missing. If he moved into an established community, he "hot-footed" it down to the local nursery. Nearly all progressive communities have a nursery or two, but not always his favorite tree. So he either bought a substitute, usually a nonlocal species, or he got out his mail order catalog and ordered a nonlocal tree.

This form of introduction has been going on continuously, though not always successfully. We have introduced nonlocal trees into almost every section of the United States. Areas such as the Great Plains perhaps have more exotic trees than indigenous ones.

Some of the mistakes made in introduction of nonlocal trees have been costly. Some trees such as Ailanthus or Tree-of-Heaven, imported from China, have become a nuisance in many areas, and are difficult to control. We have also introduced the chestnut blight from Asia, and the white pine blister rust and the Dutch elm disease from Europe.

We have even helped to shift around our own native diseases. In 1963, the Southwest was importing western gall rust on ponderosa pine trees raised at a nursery in Oregon. We already had the disease, but we helped spread it to new areas in our reforestation program. A highly destructive virus disease known as phloem necrosis has been shifted around with the American elm. Many of our Siberian elms in Flagstaff, Arizona, have a pit canker. Pole blight is serious in western white pine stands of Idaho, Montana, and Washington.

We often lose ornamental trees in communities and recreation areas. These trees take a lot of punishment each year. A new pavement job may cause an earlier-than-expected death with no apparent trace of causal agent. All sorts of pipelines border some streets. A leaky gas main has been known to cause trees to die. Insects also take their toll.

I am frequently consulted by owners of these sick trees. As a silviculturist, I may be no authority on ornamentals, but since we are addressing ourselves to forest trees used as ornamentals, we might examine some of the problems we face with nonlocal trees, some of the constraints in their use, and some suggestions on what might be done.

Seed Origin

We know that forest tree species occur over a wide range of climatic and physiographic conditions. The geneticists indicate that thousands of possible genotypes are represented in seed crops collected from wild stands (fig. 1). These stands have probably maintained a broad range of genetic variability, even in local races. In fact every seed has a unique genotype. The trees growing in a particular environmental niche represent the progeny of a small proportion of each seed crop. Those genotypes that were adapted to specific conditions survived, while others failed.

Figure 1.—Each seed has a unique genotype with thousands of possible genotypes represented in seed crops of forest stands.

Numerous studies have demonstrated the great racial variability in wide-ranging species. Ponderosa pine has been studied in many regions, usually involving collections from a wide distribution of seed sources (Squillace and Silen 1962, Larson 1966, Shearer 1966, Silen 1970, Steinhoff 1970). Douglas-fir has also been widely studied for many years (Silen 1966, Wright et al. 1970, Wright et al. 1971a). Other species that have been investigated include: lodgepole pine, western white pine, southwestern white pine, limber pine, Monterey pine, Scotch pine, red pine, white fir, blue spruce, Siberian larch, and Dahurian larch.

Exhaustive studies have also been made at single locations involving many species. The most noteworthy are the tests at the Eddy Arboretum at Placerville, California, and the Wind River Arboretum near Carson, Washington. At the Eddy Arboretum, 72 species, 35 varieties, and 90 hybrids of pine have been investigated (Liddicott and Righter 1960). The arboretum contains over 50 other species. At the Wind River Arboretum, over 400 seed lots of various species that might be suitable for planting in the Pacific Northwest have been under investigation, many dating back to 1912 (Silen and Woike 1959).

What does this all prove? The various studies have demonstrated significant differences in survival, growth, tree form, foliage color, and other characteristics. Many studies showed differences in growth of progeny from collection areas just a few miles apart. Based on studies conducted in the Great Plains, a better Douglas-fir Christmas tree and ornamental has been developed for planting in the eastern United States (Wright et al. 1970). Douglas-fir seed from near Cloudcroft, New Mexico, has been far superior to any other seed sources, even those just a few miles away, in progeny tests in Germany.[3] Young trees from sources near Cloudcroft were twice as tall as the nearest rival and had better form and color. Research in the Great Plains has provided Nebraska with an outstanding Christmas tree and ornamental, southwestern white pine (Wright et al. 1971b), which in its native habitat on the Mogollon Plateau in Arizona has little value.

Nearly all of the species tested at the Wind River Arboretum have failed to measure up to Douglas-fir for timber production, although many are suitable as ornamentals (Silen and Woike 1959).

What have we learned from these racial variation studies? Other than the good things referred to above, we have discovered that it is often difficult to beat the indigenous species. Goor (1963) pointed out that indigenous trees, when properly planted, were the best assurance of success in afforestation. Introduction of exotics should be tried, but with proper judgment. The species chosen, whether it is introduced from another country or merely moved within the same country, should fulfill a definite need (Champion and Brasnett 1958).

The necessity of matching climates has been stressed by all who have studied the racial variation in species, especially those with extensive ranges. In the Southwest, we have divided up the forested areas of Arizona and New Mexico into 10 physiographic-climatic regions

[3]Personal communication from Dr. Walter Neugebauer, Pein and Pein Nursery near Hamburg, Germany.

(fig. 2) (Schubert and Pitcher 1973). These regions were then subdivided into five to nine collection zones about 50 miles wide. Tentative ecological provinces have been defined for the true fir-hemlock forests of the Pacific Northwest (Franklin 1965). Similar seed provenance units have been established in other regions.

The question "How local is local?" has been often raised. Silen (1970) says it may be as small as the immediate area beneath the seed tree or it may be several miles. At Priest River, Idaho—where 27 races of ponderosa pine have been growing for 55 years—survival is poor for trees from seed sources more than 200 miles away (Steinhoff 1970). Ponderosa pines from a western Montana source all died when planted in eastern Montana, while those planted in western Montana had excellent survival (Shearer 1966). Siberian and Dahurian larches showed significant survival differences from narrowly separated origins (Cunningham 1972). On the other hand, however, many exotics from Europe and Asia have survived well at both the Eddy Arboretum (Liddicott and Righter 1960) and at the Wind River Arboretum (Silen and Woike 1959). Special care should be exercised with species of wide, and particularly with discontinuous, distribution; the geographical races

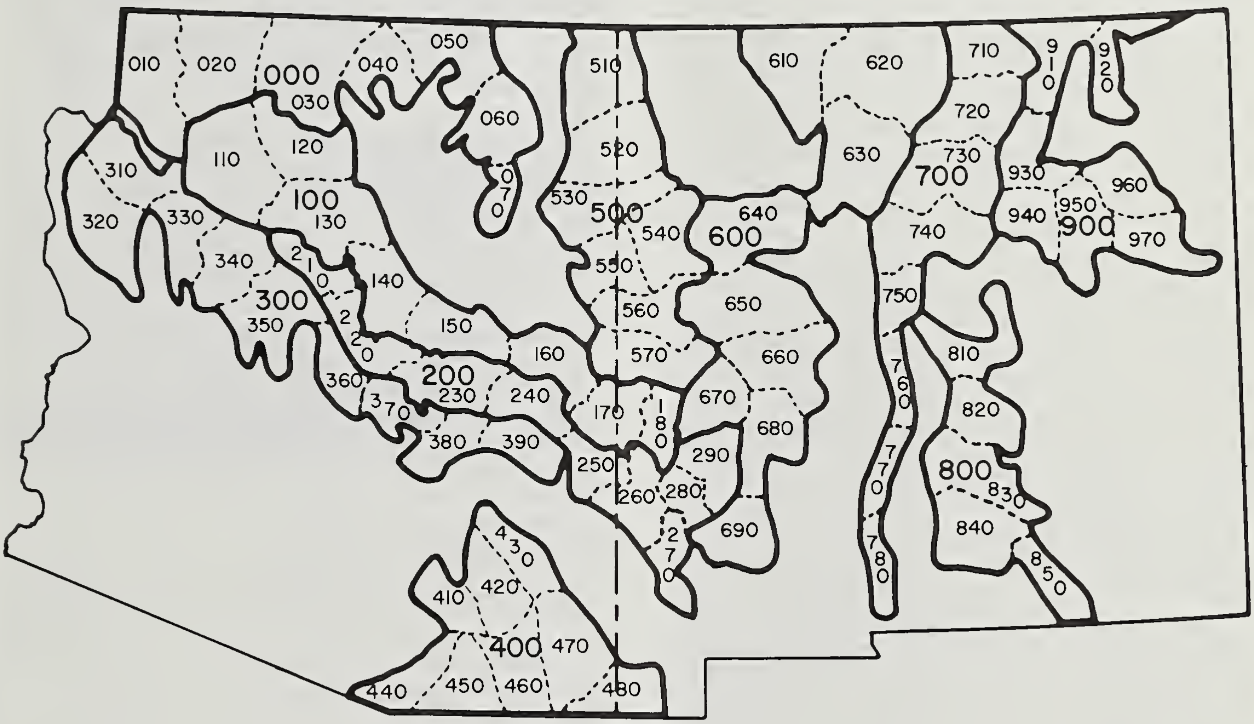

Figure 2.—Physiographic-climatic zones defined for the Southwest Region to match areas of similar environmental conditions (Schubert and Pitcher 1973):
000 Northwest Plateaus (Seed Zones 010-070)
100 Central Plateaus (Seed Zones 110-180)
200 Mogollon Slope and Highlands (Seed Zones 210-290)
300 Central Highlands (Seed Zones 310-390)
400 Southeast Desert Highlands (Seed Zones 410-480)
500 Chuska-Zuni-Gallo Highlands (Seed Zones 510-570)
600 East Continental Highlands (Seed Zones 610-690)
700 East Rio Grande Highlands (Seed Zones 710-780)
800 Sacramento-Guadalupe Range (Seed Zones 810-850)
900 Northeast Plains (Seed Zones 910-970)

and ecotypes within them may vary widely in performance in a new site (Champion and Brasnett 1958).

Climatic Factors

Climatic extremes have been the major cause of mortality. Frequently, when trees are planted in sheltered spots, climatic extremes of the areas that could cause damage are abated (Silen 1966). Extreme low temperatures seem to be the most limiting factor, though extreme droughts have also been responsible for high mortality (Champion and Brasnett 1958).

Temperature

According to Good (1953), "There are no parts of the world where the temperatures are too high for growth and reproduction," so the limiting factor would be low temperature. Therefore, lowest recorded temperatures for the area should be determined before selecting planting stock. Low temperature eliminated all the west-slope Sierra Nevada sources from California that were planted at Fort Valley Experimental Forest near Flagstaff, Arizona (Larson 1966). Monterey pines planted in Oregon (Krygier 1958) and in the Sierra Nevada of California (Schubert and Adams 1971) were killed by low temperatures. Low temperatures have prevented the extension of redwood to the north (Mason 1936), and caused considerable damage to exotics in the Wind River Arboretum (Silen and Woike 1959).

Planted sugar pines in the Sierra Nevada of California were found to be more affected by a sudden drop in temperature than were incense-cedars or ponderosa pine (Schubert 1955). In the Inland Empire, progenies from localities with a wide range in temperature were most resistant to frost damage (Squillace and Silen 1962).

Long-term studies are needed to establish the low temperature threshold (Silen 1970). Near San Francisco, from 3 to 4 million nonnative eucalyptus trees, planted near the turn of the century, were killed or severely damaged by cold in 1972. Nearly all nonlocal trees planted in an arboretum at Chico, California, were wiped out by the 1932 freeze after the trees had made good growth for over 20 years.[4] None of the native trees were damaged.

[4]*Personal communication from Woodbridge Metcalf (deceased), former Extension Forester, School of Forestry, University of California, Berkeley.*

Native trees are also susceptible to extreme temperature, but seldom are killed (Parker 1953, Duffield 1956,). Severe topkill of native Coulter pines and bigcone Douglas-fir has occurred in southern California (Wagener 1949). Ponderosa pine ecotypes east of the Cascades in Washington and Northern Idaho appear to be more resistant to severe winter temperatures than those on the west side of the Cascades in Washington (Daubenmire 1957).

Trees from high-elevation sources, when planted at lower elevations, burst buds earlier than in the native site and often suffer severe damage by a late freeze (Goor 1963, Silen 1970). These same low temperatures may damage individual trees in local populations, but the damage is usually less severe than that suffered by offsite trees.

Snow and Ice

Snow and ice also cause severe damage to offsite trees. Siberian elms in Flagstaff, Arizona, have suffered severe breakage by heavy wet snows. Larches in the Wind River Arboretum have suffered considerable breakage (Silen and Woike 1959). Snow breakage in pole-sized ponderosa pine has been more severe in stands of high density than in low (Powers and Oliver 1970). Snowbending of sugar pine and ponderosa pine seedlings was found to be a temporary injury unless too severely bent or broken (fig. 3) (Schubert and Adams 1971). Ice has caused considerable damage in some areas, especially to trees from warmer seed sources (Jones and Wells 1969).

From these observations, we can avoid some of the low temperature, ice, and snow damage by selecting species that have demonstrated resistance. Much, but not all, damage can be avoided by selecting trees from areas having a similar climate.

Drought

Forest types are to a great extent determined by the amount of precipitation (Pearson 1931, Champion and Brasnett 1958, Goor 1963). Planted trees, with their reduced root systems, generally suffer considerable damage, particularly where spring precipitation is low and erratic (Schubert et al. 1970, Schubert and Adams 1971). Wildling stock is generally a poor risk (Schubert and Adams 1971), but many people still dig up seedlings from the forest for planting in their yards. The failure of the ponderosa pine from western Montana planted in eastern

Montana was reported to be due to drought (Shearer 1966). Severe drought damage has occurred at the Wind River Arboretum (Silen and Woike 1959).

Figure 3.—Young ponderosa pines bent by heavy wet snow during early spring usually recover unless the trees are severely bent or broken.

Ponderosa pine is known to be quite drought resistant (Pearson 1931). Trees with reported drought resistance include: Tree-of-Heaven, green ash, velvet ash, boxelder, northern catalpa, Siberian elm, common hackberry, black locust, Russian mulberry, Russian-olive, tamarisk, bur oak, sugarberry, honeylocust, eastern redcedar, white fir, and the spruces (Gill 1949, Wright and Bretz 1949).

Drought is normally not a problem in urban plantings. The critical period in survival of planted trees is during the first couple of years. Trees that come from areas where summer rains are normal should be watered when planted on droughty sites. Water stresses may be reduced by removal of competing vegetation and by mulching (Schubert et al. 1970, Schubert and Adams 1971).

Soil Factors

The soil requirements for optimum development and the range of conditions tolerated vary greatly for different tree species, and are second only to climatic factors in determining natural distribution and wise selection for planting (Lutz and Chandler 1947, Champion and Brasnett 1958, Goor 1963). In relatively small regions of uniform climate, the nature of the parent material is probably more important than any other single factor in determining the character and productivity of soils (Lutz and Chandler 1947). In the Black Hills, soil depth was found to have a stronger influence on site productivity than parent material although soil depth is often related to parent material (Myers and Van Deusen 1960). In Montana, ponderosa pine growth response was related to soil type, effective soil depth, landform, and moisture availability (Cox et al. 1960). On selected sites in Arizona, Colorado, Idaho, and Utah, water-holding capacities of the soil varied from 25.8 to 70.0 percent, and wilting coefficients from 3.3 to 16.1 percent.

Soils have a significant influence on the type of forest they support (Pearson 1931, Lutz and Chandler 1947). In the Southwest, about half of the ponderosa pine sawtimber occurs on soils derived from basaltic rocks, and planted trees readily become established (Pearson 1931). Ponderosa pine has been most productive on Permean limestones, intermediate on calcareous sandstone, and least on siliceous sandstone and cinders. Rocky Mountain juniper occurs more abundantly on limestone than sandstone where both are present (Lutz and Chandler 1947). Northern white-cedar was found to occur most abundantly on calcareous soils, whereas jack pine was most abundant on acid soils (Fernald 1919).

Survival of spring-planted trees was highest on heavier soils in the northern Rockies, whereas survival of fall-planted trees was highest on light- and medium-textured soils (LeBarron et al. 1938). In Montana, ponderosa pine stands were found to have their best root development in medium-textured soils and poorest in fine-textured soils (Cox 1959). Root concentration was more uniform in medium-textured soils and decreased abruptly below 18 inches in fine-textured soils. Lodgepole pine takes over the site from ponderosa pine in areas having a tight clay subsoil that prevents good drainage (Howell 1931). Windthrow is a problem on many of the areas with a clay hardpan near the surface.

Alkali soils are a problem in some areas of the Great Plains and northern Rocky Moun-

tains. Some of the species that can tolerate and grow on alkali soils include: common hackberry, Russian-olive, velvet ash, Norway maple, tamarisk, and eucalyptus (Gill 1949, Wright and Bretz 1949). Soil alkalinity is one of the limiting factors in establishment of oak.

Fortunately, alkali soils are not too widespread. Some corrective action to reduce the adverse effect of alkali include: Leaching with underdrainage, removal of the alkali incrustations, and treating with gypsum or sulfur (Lutz and Chandler 1947). Areas treated with gypsum or sulfur must be kept moist for the reaction to take place. Trees with deep rooting characteristics are most suitable for planting in alkali soils. Tree establishment may be improved by digging considerably larger holes than is used in ordinary planting and replacing the alkali soil with good rich sandy loam.

Most adverse soil conditions can be at least partly corrected for community or recreation-area tree planting. Some corrective treatments may be expensive, but the total job is rather small. Relatively few trees are planted in urban areas compared to forest plantations. On difficult problem soils, an expert soil scientist should be consulted.

Mycorrhizae

Good development of mycorrhizae on roots of forest trees has generally been accepted as necessary for good survival and growth (fig. 4). Monterey pine planting stock from new nurseries in western Australia was satisfactory only when seedbeds were inoculated with soil taken from old pine nurseries (Cromer 1935). This practice is not always recommended, however, as it may result in the introduction of serious pathogens. A preferable source would be a healthy plantation or native forest. Furthermore, fumigants used in nurseries to destroy harmful fungi also kill mycorrhizal fungi (Wright 1957).

Many plantation failures have been due to the absence of mycorrhizae. Many failures listed as due to "unknown" causes may also have been due to the absence of mycorrhizae. A possible example is the rapid and complete failure of Monterey pine planted on 5,000 acres of newly cleared land in Florida (Schaer 1959). In the Southeast, mycorrhizae were reported to be vital for survival of slash pine (Jorgensen and Shoulders 1967) and loblolly pine (Shoulders and Jorgensen 1969).

Figure 4.—Mycorrhizal fungi on roots of forest trees are necessary for good survival and growth in afforestation.

Mycorrhizal mycelia are probably more effective than root hairs in reestablishing early contact with the soil (Smith 1962), are important in soils low in available nutrients (Wright 1957), and protect the plant from pathogenic fungi (Cromer 1935).

Plantings on areas which have never been forested or which have remained without a forest cover for a number of years have been particularly difficult to plant successfully (Schubert et al. 1970, Schubert and Adams 1971). Sometimes phenomenal success follows mycorrhizal inoculation. In Puerto Rico, attempts to establish *Pinus caribaea* failed repeatedly until someone placed forest soil rich in mycorrhizae around 3 of the 5,000 planted trees.[5] The three inoculated trees were 24 to 30 feet high in 5 years, whereas most of the others were dead or severely stunted.

Mycorrhizae have been reported on 56 conifer and 73 broadleaf species (Trappe 1964).

The lessons to be learned from these experiences are quite obvious, yet we continue to grow and plant trees without mycorrhizal roots. Much of the containerized stock produced for planting is grown in sterile media. When planted on old burns or clearcuts, these trees may fail to survive due to "unknown causes."

Figure 5.—Bark beetles cause considerable damage to trees in concert with other factors such as street paving and building construction.

Insects

Insects are present everywhere, but not all are harmful. At the Wind River Arboretum, insects were reported to be a problem on individual trees, but did not cause the failure of any species (Silen and Woike 1959). The possibility of severe damage is ever present, particularly in introduced species or under intensive cultural practices.

Insect damage in recreation areas and communities is particulary serious due to the high esthetic value attached to each tree (fig. 5). Green ash, which is widely planted as an ornamental and for windbreaks, has been attacked by various species of wood borers (McKnight and Tunnock 1973). The likelihood of borer damage is so great that it limits the use of green ash in parts of North Dakota, South Dakota, and Montana. These native borers have become more abundant as the supply of host material increased.

The western spruce budworm causes more damage on western larch than normally occurs on other conifers (Schmidt and Fellin 1973). The larvae normally confine their feeding to foliage, but on western larch they also feed on and sever stems of current-year terminals and lateral shoots. Both the amount and severity of damage is reported to be increasing annually.

The carpenterworm has attacked many introduced trees in the Plains and northern Rocky Mountains. It has damaged green ash, Russian-olive, honeylocust, black walnut, black locust, poplar, cottonwood, willow, elms, soft maple, pear, cherry, and lilac.

Early detection and treatment are necessary to keep these and other insects under control. Since control methods vary, it is advisable to seek advice from an expert entomologist.

Diseases

Many native diseases take a heavy toll of our forest trees each year. Over the years, we have imported a few which have caused exten-

[5]*Based on comments by James Trappe at the "Artificial Forest Regeneration Workshop" held at Ogden, Utah, September 7-8, 1964.*

sive damage. The chestnut blight, Dutch elm disease, and white pine blister rust have received the greatest attention. The chestnut blight has essentially eliminated the American chestnut, except possibly for a few escapees. The white pine blister rust is a threat to all white pine, native or exotic. The Dutch elm disease is on the move westward, and has reached the foothills of the Rockies in Colorado.

Fomes root rot is found worldwide. *Fomes annosus* is one of the most serious pathogens of conifers in the temperate climatic zone. Systematic disease surveys in California during the past two decades suggest that *Fomes annosus* root rot is becoming increasingly significant as a limiting factor in the intensive management of conifer plantations (Bega and Smith 1966). In young pine plantations, the disease invades and kills the root cambium rapidly and the tree dies. In the true fir and other non-pine species, death of the tree is considerably slower. Trees should not be planted within the root zone of a tree suspected of having *Fomes annosus* root rot.

Dwarf mistletoes are widely recognized as damaging agents to shade trees, horticultural plants, and forest trees. Mistletoes cause reduced vigor and growth, poor fruit or seed crops, malformation of woody tissues, sparse foliage, dead tops, predisposition to insect and other disease attacks, and premature death of the host tree.

Many species are infected by mistletoes. A survey in western Montana indicated that dwarf mistletoe was present on 23 percent of the 3.4 million acres of commercial timberland (Graham 1964). Heavy infections were reported in Douglas-fir and western larch stands in northeastern Washington (Graham and Frazier 1962). Brewer spruce has been severely infected by fir, sugar pine, and hemlock dwarf mistletoes (Hawksworth et al. 1970).

Dwarf mistletoe causes more damage to ponderosa pine than any other disease (Kimmey and Mielke 1959). Lodgepole pine dwarf mistletoe was found to be more common on ponderosa pine than previous reports indicated, and occurs frequently outside the range of ponderosa pine dwarf mistletoe (Hawksworth 1968a). Ponderosa pine dwarf mistletoe frequency is highest on gentle slopes and lowest on steep slopes (Hawksworth 1968b). This places it down among communities and recreational areas.

Nonlocal stock may be more seriously affected than the native trees. Much of the poor success of exotics has been attributed to disease. Nonlocal trees may be very susceptible to native diseases, but susceptibility has been reported to vary by seed origin (Peterson and Read 1971).

We can do much to reduce damage and prevent losses. Many diseases are brought in on the planting stock. A safer way is to bring in nonlocal trees by seed. Trees known or suspected to be susceptible to native diseases should not be planted in the diseased areas. Trees planted in communities and other heavy-use areas receive more abuse than those in a forest. Proper treatment, care, and protection are therefore essential to their continued health and vigor. Too much "good treatment" may not be wise, however. For example, Russian-olive requires little water, and if watered too much may die from a root disease that thrives only in continuously moist situations.[6]

Animal Damage

Many tree species appear to be favorite food for certain animals (Schubert et al. 1970, Schubert and Adams 1971). Livestock normally are no problem in communities, but may at times invade recreation areas. Big-game animals relish many broadleaf species and some conifers. At the new Fort Valley Arboretum near Flagstaff, Arizona, elk browsed all the new growth of the oak, maples, elms, and other hardwoods that had been planted earlier in the spring.[7] It was enjoyable to watch the elk gracefully leap over the fence, but then after the damage was noticed the enjoyment faded rapidly.

Some animals show preference (fig. 6). In the above example, elk liked the hardwoods better than the conifers. The Abert squirrel in northern Arizona gets about 95 percent of his food from ponderosa pine (Schubert and Adams 1971). In a hybrid plantation in California, porcupines killed from 2 to 37 percent of the ponderosa pine hybrids, with only minor damage to Jeffrey pine (Schubert and Adams 1971). The black-tailed jackrabbit browsed the ponderosa pine from sources west of the Continental Divide more heavily than the sources from the east (Read 1971). Rabbits, deer, and porcupines have shown different preferences for plants of different sources in the Pacific Northwest (Squillace and Silen 1962).

The high-value trees planted in recreation areas need to be protected from animals until they are out of danger. Young trees should be

[6] *Personal communication from Paul Lightle, formerly Principal Pathologist with the Rocky Mountain Forest and Range Experiment Station, Albuquerque, New Mexico.*

[7] *Personal communication from Dr. Donald Wommack, Professor of Forestry, Northern Arizona University, Flagstaff, Arizona.*

Figure 6.—Porcupines have shown a decided preference for ponderosa pines of certain genotypes.

surrounded by an appropriate fence, or treated with an animal repellent. Larger trees may require metal bands to prevent climbing by porcupines. In areas with a heavy gopher population, a metal band or fine mesh screen can be used.

Species Selection

Indigenous species would be the most likely to survive and grow, but in some areas the right kind may not be available to meet the desired need. Most communities have a number of species, particularly in parks and on campuses, and may serve as a "local arboretum." These trees could be examined for: their suitability for shade, screen, or esthetics; their resistance to insects and disease; their ability to withstand cold, snow, ice, and wind damage; and their resistance to abuse by man. These "town-trees" may not give a true picture of their cold-hardiness or drought hardiness, however, because of the heat output from houses and the heavy watering.

Lists are available that give characteristics and suitability of tree species for specific areas such as the Plains (Wright and Bretz 1949) and the Rockies (Gill 1949). New trees are continually introduced—not always successful or wise choices—by homeowners or through research. Japanese larch was suggested as a new tree for eastern Nebraska following a 10-year test by research personnel (Read 1970), although we realize the tree may still succumb at a future date due to some extreme weather condition, bug, or disease. These factors often work in concert. Once a tree is weakened by drought, it falls prey to insects or diseases.

Many trees can be used in their youth that do poorly later. A planned rotation will permit use of offsite material that would not be possible otherwise. Where we have an established native tree population that does not meet all the requirements for diversity, we can always resort to: group-selection cutting to create small openings for vertical diversity as new trees become established; variable-density thinning to create horizontal diversity; or underplant with a shade-tolerant species to get species diversity. These methods are commonly used in travel influence zones through forested highways.

Summary

I feel we can solve many of the constraints on the use of nonnative trees in community and recreation areas, provided we:

1. Select a species that is reasonably adapted to the local climatic and edaphic conditions.

2. Select a species that is resistant to native insects and diseases.

3. Plant a tree that is free of insects or diseases so that the native trees are not endangered.

4. Inoculate the soil or tree roots with mycorrhizae free of other pests if the proper mycorrhizae are absent.

5. Prepare the site to eliminate root competition for moisture or correct some undesirable soil condition.

6. Water the plant, if necessary, to give the tree a good start and maintain good vigor in its new environment.

7. Plan to replace nonnative trees at regular intervals that grow well in their youth but lose vigor later.

8. Provide the necessary care and protection the tree needs in its new habitat.

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Describes important factors that affect the health and vigor of forest trees introduced into communities and high density recreation areas. Seed origin, climatic and edaphic factors, and mycorrhizae are discussed first followed by insects, diseases, animal damage, and species selection. Relevant literature is covered along with observations and experience. Treatise is intended to point out the critical considerations in use of nonlocal trees and to serve as a reference guide in making wise species selection.

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